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13. SUPPLEMENTARY NOTES

14. ABSTRACT
The project is devoted to the problem of the numerical simulation of the effective elastic, thermo and electro conductive properties of open-cell foam materials. The Laguerre tessellation procedure is applied for the construction of skeletons of random foam microstructures with prescribed distributions of the cell diameters. A four-parametric approximation of the ligament shapes in the open-cell foams is proposed. For simulation of the elastic properties of open –cell foams, a version of the finite element method based on the Timoshenko beam finite element is developed. The method is used for calculation of stresses and strains in the foam ligaments and the solution of the homogenization problem. The size of the representative volume element (RVE) for reliable calculations of the effective elastic properties of the foam materials is evaluated on the basis of series of numerical experiments. The dependences of the effective elastic properties of the open-cell foams on cell size distributions and on ligament shapes are obtained and analyzed. The problem simulation of the effective electro and thermo conductive properties of open-cell foam materials with slim highly conductive ligaments has a specific feature. Its solution depends on two small parameters: the ratio of the typical length and the cross-section size of the ligaments. Principle terms of the asymptotic solutions (with respect to these parameters) for the fields inside the ligaments are obtained and used in the framework of a finite element method for the numerical simulation of the fields inside the representative volume element of the foam material. Effective conductivity constants of the foams are obtained by averaging the detailed fields in the ligaments over the RVE. The number of cells inside the RVE for reliable calculations of the effective conductivities is indicated. Dependences of the effective conductive properties on the details of the foam microstructure are obtained and analyzed.

15. SUBJECT TERMS

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FINAL PERFORMANCE REPORT

December 2006-December 2007

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06IO004

(Computer Simulation of Physical and Mechanical Properties of Carbon Foams)

2. Objectives:

- Formulation of adequate geometrical models of micro structures of foam materials,
- Development of the numerical methods for the calculation of physical fields in the representative volume element of the foam material,
- Evaluation of the macro mechanical and physical properties of carbon and metallic foams on the basis of numerical experiments with the representative volume element,
- Comparison of the results of numerical simulations and experimental measurements of physical properties of foam materials.

3. Status of effort:

In the reported period, the main progress was achieved in simulation of thermo and electro conductive properties of open-cell foam materials. An asymptotical method for calculation of temperature and electric fields in a slim highly conductive ligament was developed. This asymptotic solution was used in the framework of a finite element method for the calculation of stationary temperature and electric fields in all the ligaments of open-cell foam materials and evaluation of the effective thermo conductive, dielectric, and electro conductive properties of the foam representative volume element. The theoretical predictions were compared with experimental data presented in the literature.

We started to work on a new approach to the solution of the homogenization problem for open-cell foams. In this approach, every typical cell of foam is considered as embedded in a medium with effective properties of the foam. These effective properties connect the mean values of the field and field flux inside the elementary cell of the foam (self-consistent effective medium method for open and close-cell foams).

4. Annual accomplishment:

The developed methods of simulation of the microstructure of the open-cell foams and solution of the homogenization problem allowed us to obtain the following new results.

1. For reliable calculations of conductive properties of the open-cell foams, the representative volume element (RVE) should contain about 1000-1200 cells. This RVE is similar to the RVE for the calculation of the effective elastic properties.
2. The method allowed us to perform studying dependences of the effective properties of the open-cell foams on the distribution law of the cell sizes, and on the form of a typical ligament in the RVE. It turns out that the influence of the cell-size distribution on the conductive properties is much less than such an influence on the elastic properties. A similar fact was discovered in relation to the influence of cross-section forms of the ligaments on the effective properties of the open-cell foams. The effective conductivity is much less sensitive to the ligament cross-sections than the effective elastic modules. Only the total area of cross-section and the distribution of this area along the ligament axes are important characteristics for the effective conductivity.
3. The predictions of the method are close to experimental data existing in the literature. Finally, the method allows us to give reliable predictions of

conductive properties of open-cell foams with low volume concentration of the hard phase. In the method, the conductivity of the gas or liquid phase inside the foam is also taken into account. It helps material engineers to create foam materials which properties are optimal to the exploitation conditions.

4. An original numerical method for the calculation of fields inside an isolated inclusion with complex structure embedded in a homogeneous medium was developed. The method will be used in the framework of a self-consistent effective medium method for the solution of the homogenization problems for foam materials.

5. Personnel Supported:

The team that works on the project consists of the professors of the Mechanical Engineering Department of the Technological Institute of Monterrey (Campus of the México State):
Dr. Serguei Kanaoun,
Dr. Oleksander Tkachenko,
Dr. Sadegh Babaii.
The student of the master program M. A. Garcia Luna takes part in this work.

6. Publications:

The results of the work concerned elastic properties of open-cell foams were published in:

S. Kanaun and O. Tkachenko. Representative volume element and effective elastic properties of open-cell foam materials with random microstructures. Journal of the Mechanics of Materials and Structures, 2007, v.2, N8, 1607-1628.

The solution of the homogenization problem for conductive properties of open-cell foams was presented in the paper:

S. Kanaun and O. Tkachenko. Effective conductive properties of open-cell foams. International Journal of Engineering Sciences, 2008, accepted for publication.

A new numerical method for the solution of the homogenization problem was developed and presented in the papers:

S. Kanaun y S. Babaii Kochekseraii, A numerical method for the solution of 3D-integral equations of electro-static theory based on Gaussian approximation functions. Applied Mathematics and Computation, 2007, v.184, 754-768.

S. Kanaun and S. Bababii Kochekseraii. Effective conductive and dielectric properties of matrix composites with inclusions of arbitrary shapes. International Journal of Engineering Sciences. 2008, vol. 46/2, 147-163.

7. Interactions

a. The results obtained in the reported period were presented and discussed in the Air Force Office of Scientific Research Grantees'/Contractors' Meeting "Mechanics of Multifunctional Materials &Microsystems", Monterey, CA, June 25-28, 2007.
b. The work on the numerical method for the solution of the homogenization problem was presented in the International Conference "Continuum Models and Discrete Systems (CMDS11)", Paris, France, July 29-August 3, 2007.
c. The results of this work are interesting for materials engineers and researchers of various institutions mentioned in the list below:

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8. New discovery, inventions, or patent disclosers.
   None.
9. Honors/Awards.
   None.